Cloud type comparisons of AIRS, CALIPSO, and CloudSat cloud height and amount

by

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Motivation – 1

- **Results are submitted:**
  - Kahn, B.H., M.T. Chahine, G.L. Stephens, G.G. Mace, R.T. Marchand, Z. Wang, C.D. Barnet, A. Eldering, R.E. Holz, R.E. Kuehn, and D.G. Vane (2007), Cloud type comparisons of AIRS, CALIPSO, and CloudSat cloud height and amount, *Atmos. Chem. Phys. Discuss.*, **7**, 13915–13958.

- **Clouds and Earth's climate**
  - Radiative heating/forcing several times to orders of magnitude greater than climate change constituents (e.g., trace gases, aerosols)
    - (e.g., Hartmann et al. 1992; Forster et al. 2007)
  - Critical component of hydrological cycle (e.g., Webster 1994)
    - Very small amounts of water have very large climatic impacts
  - Cloud feedbacks at heart of climate forecast uncertainty (e.g., Stephens, 2005; IPCC)
  - Many other impacts

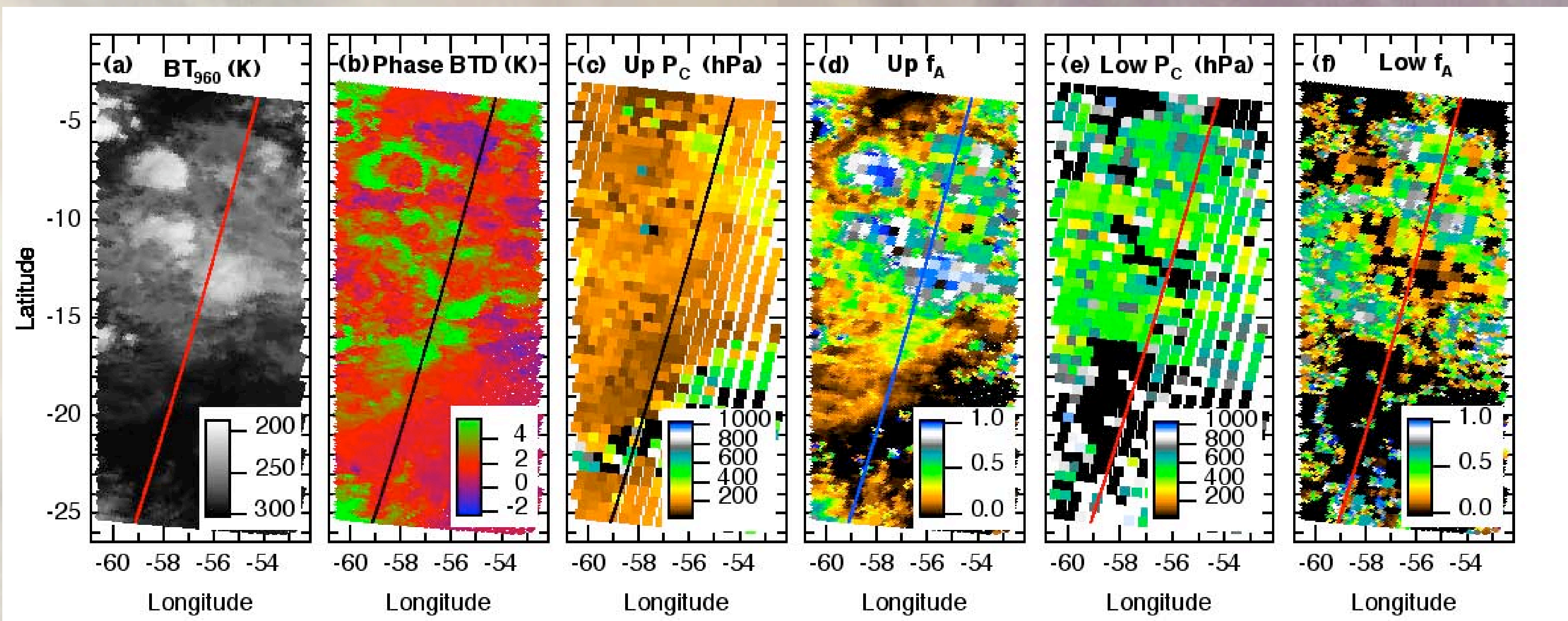
Motivation – 2

- **Quantify precision of IR remote sensing of cloud properties**
  - Characterize uncertainties, strengths, weaknesses
  - Ongoing re-assessments of algorithm changes
- **Collocated CloudSat and CALIPSO observations**
  - Active measurements – precise cloud detection, vertical profiles
  - Cloud-type assessment
- **AIRS cloud height and amount used in retrieval of bulk, microphysical, optical, other cloud properties**
- **Move towards combined retrievals using full power of A-train**

Outline

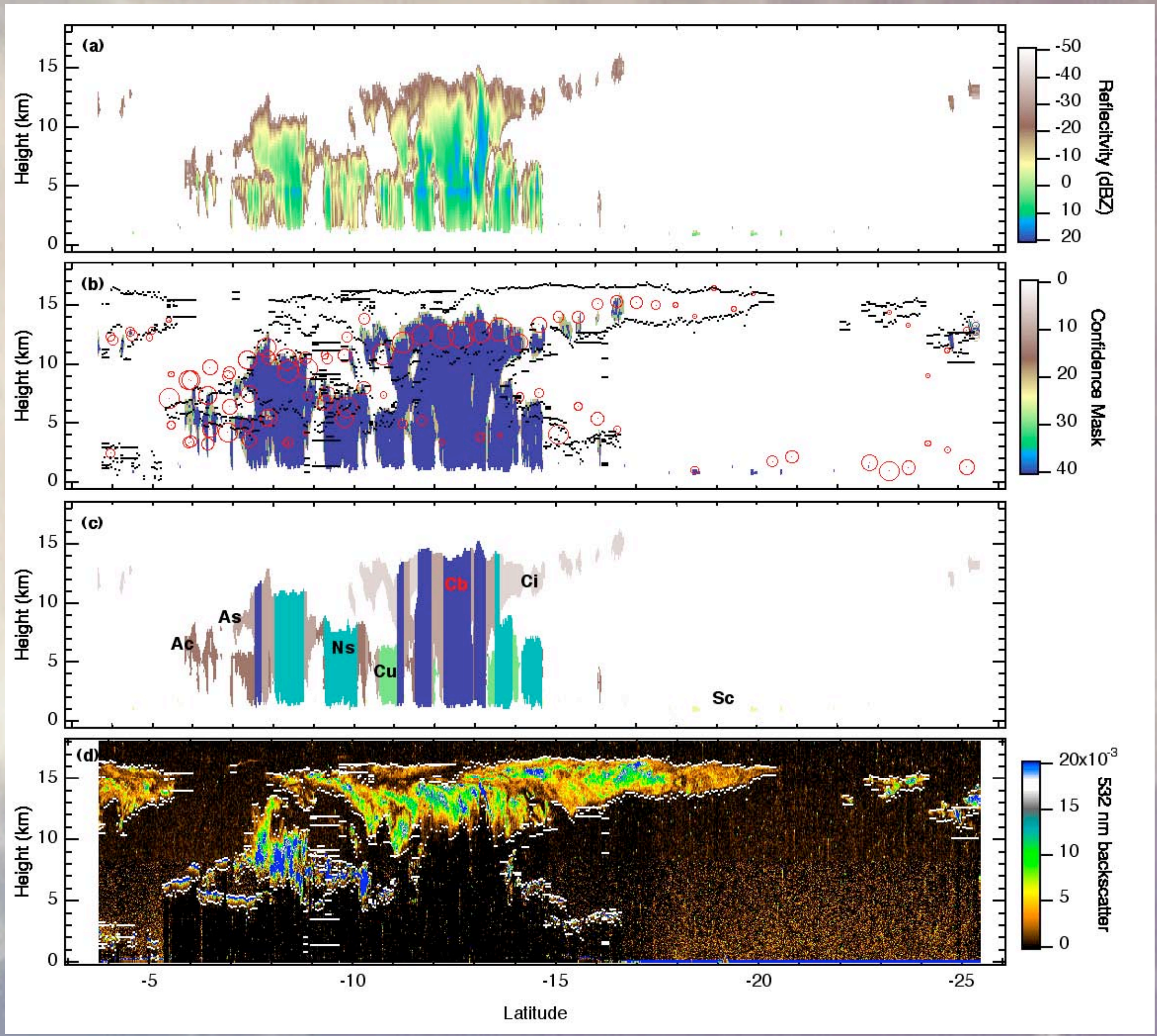
- **An illustrative granule: the view from AIRS, CloudSat, and CALIPSO**
- **FOV-scale comparisons: how to quantify?**
- **A five-day climatology**
- **CloudSat/AIRS comparisons by cloud type**
  - Show joint PDFs
  - V4/V5 differences
  - Insights gained from comparisons
- **CALIPSO/AIRS comparisons**
  - Differences and similarities compared to CloudSat
  - V4/V5 differences
- **Take home messages**

An Illustrative Granule in Tropical Indian Ocean

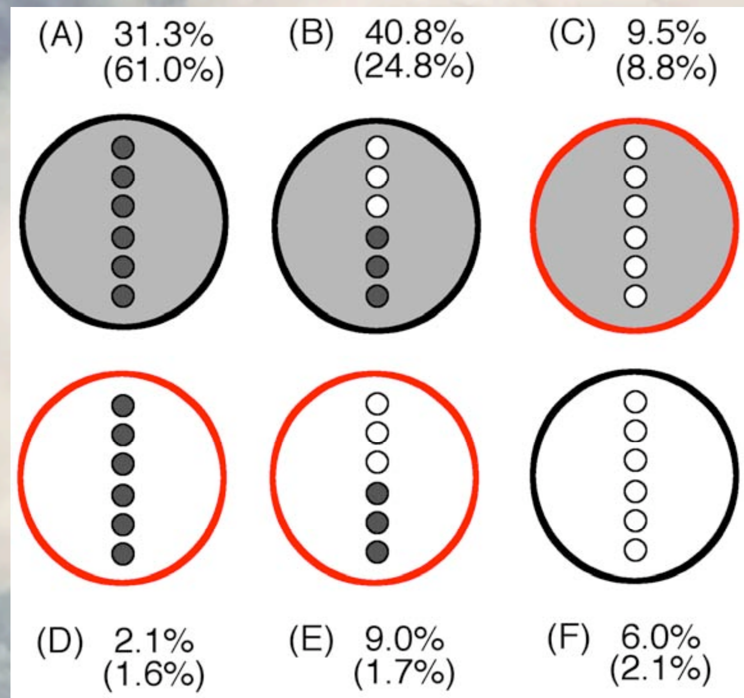


BT_{960} $BTD_{1231-960}$ Up CTP Up ECF Low CTP Low ECF

An Illustrative Granule in Tropical Indian Ocean



Match CloudSat and CALIPSO to AIRS FOV



AIRS/CloudSat
(AIRS/CALIPSO)

AIRS Cloud
CC Homog Cloud

AIRS Cloud
CC Hetero Cloud

AIRS Cloud
CC Homog Clear

AIRS Clear
CC Homog Cloud

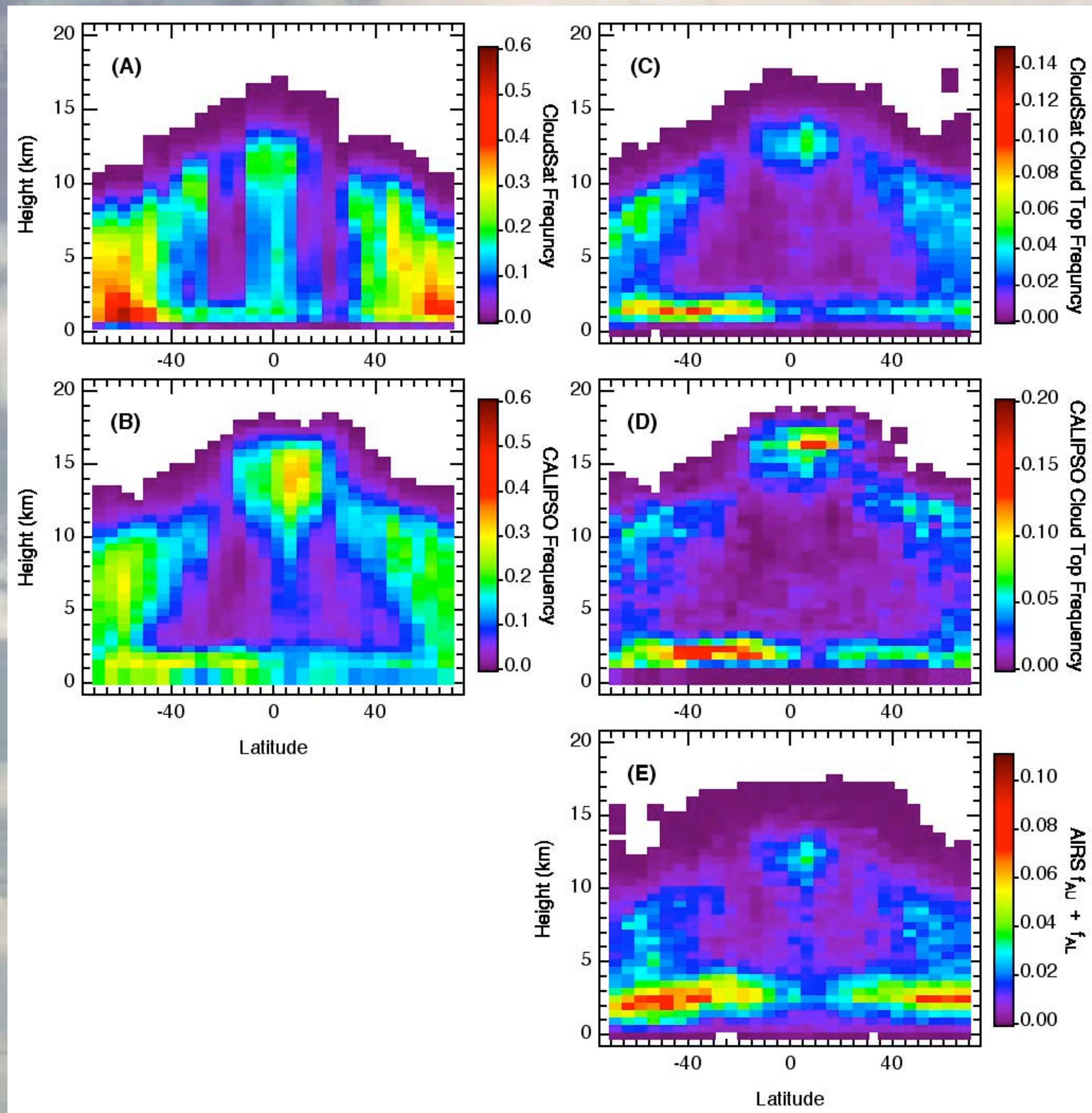
AIRS Clear
CC Hetero Cloud

AIRS Clear
CC Homog Clear

Five-day Zonally Averaged Cloud Frequency

All CloudSat

All CALIPSO



CloudSat
Cloud Top
Only

CALIPSO
Cloud Top
Only

AIRS
Upper +
Lower ECF

Five-day Cloud Frequency $\pm$ 70º lat

Instrument	% Clear	% Cloudy
CloudSat	48.1	51.9
CALIPSO (5 km)	22.7	77.3
AIRS ($f_A \geq 0.01$)	19.6	80.4
AIRS ($f_A > 0.0$)	17.1	82.9

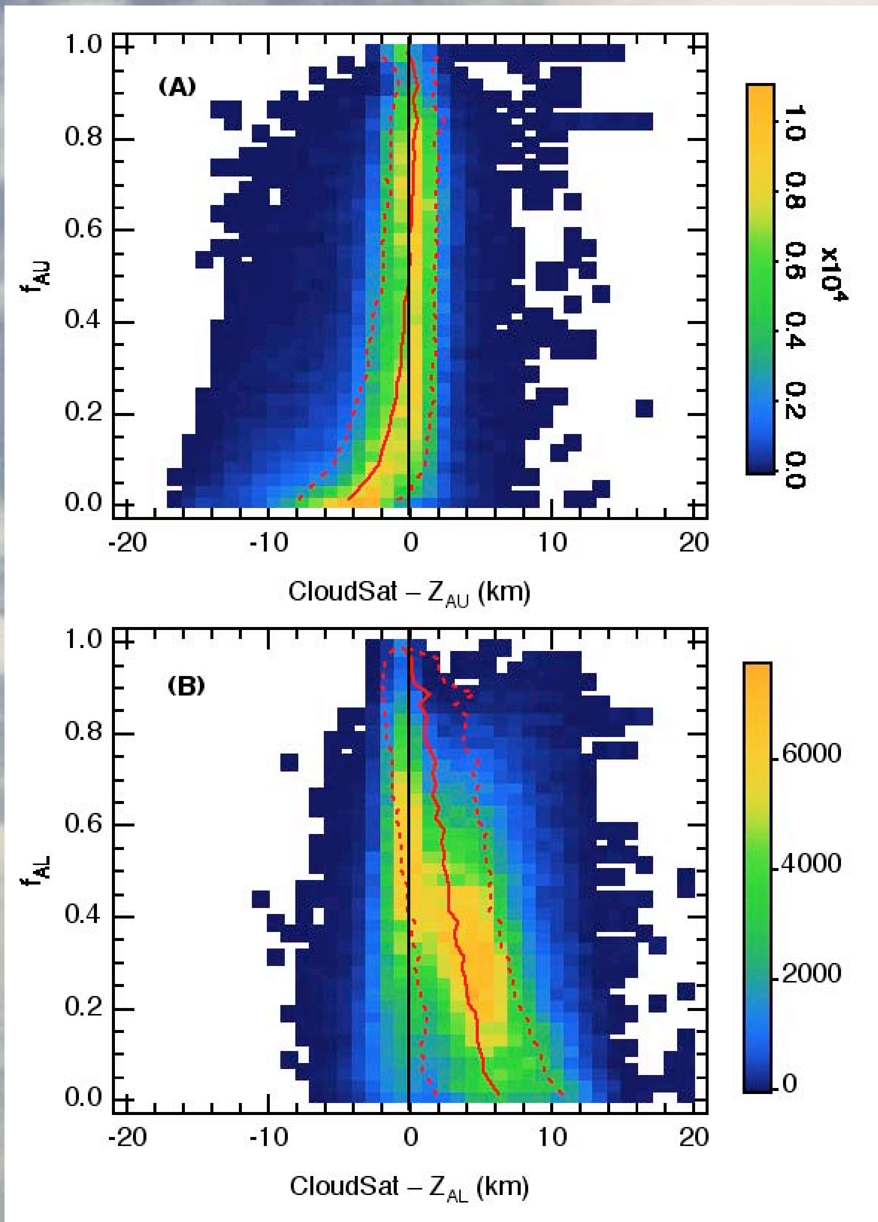
Percentages vary due to instrument sensitivity, resolution of FOV, algorithm differences, etc.

Significant Contribution from Size of FOV

Northern Mid-latitudes (20 to 60N)					Tropics (20S to 20N)				
%	Total	Thin	Thick	Opaque	%	Total	Thin	Thick	Opaque
Resolution: 1 km					*Resolution: 1 km*				
High	23.2	5.1	12.6	5.5	High	31.3	10.9	12.2	8.2
Middle	17.1	0.3	3.9	12.9	Middle	5.5	0.1	0.9	4.5
Low	31.2	0.0	0.0	31.2	Low	30.2	0.0	0.0	30.2
Clear	28.5				Clear	33.1			
Resolution: 5 km					*Resolution: 5 km*				
High	23.7	5.6	13.2	4.9	High	31.9	11.6	13.0	7.3
Middle	17.9	1.5	5.5	10.9	Middle	5.2	0.2	1.0	4.0
Low	39.0	7.1	10.1	21.8	Low	40.2	10.5	10.6	19.1
Clear	19.4				Clear	22.7			
Resolution: 10 km					*Resolution: 10 km*				
High	23.7	5.7	13.4	4.6	High	32.7	12.4	13.7	6.6
Middle	17.7	1.7	5.9	10.1	Middle	5.1	0.3	1.1	3.7
Low	40.7	8.3	12.5	19.9	Low	41.7	12.3	12.4	17.0
Clear	17.9				Clear	20.5			
Resolution: 20 km					*Resolution: 20 km*				
High	24.3	6.3	13.9	4.1	High	33.5	13.4	14.5	5.6
Middle	18.0	2.0	6.5	9.5	Middle	4.7	0.3	1.0	3.4
Low	42.0	9.5	14.5	18.0	Low	43.4	14.5	14.1	14.8
Clear	15.7				Clear	18.4			

Lifted from Menzel et al., "**MODIS global cloud-top pressure and amount estimation: Algorithm description and results**", *J. Applied Met. Climatol.* (in press)

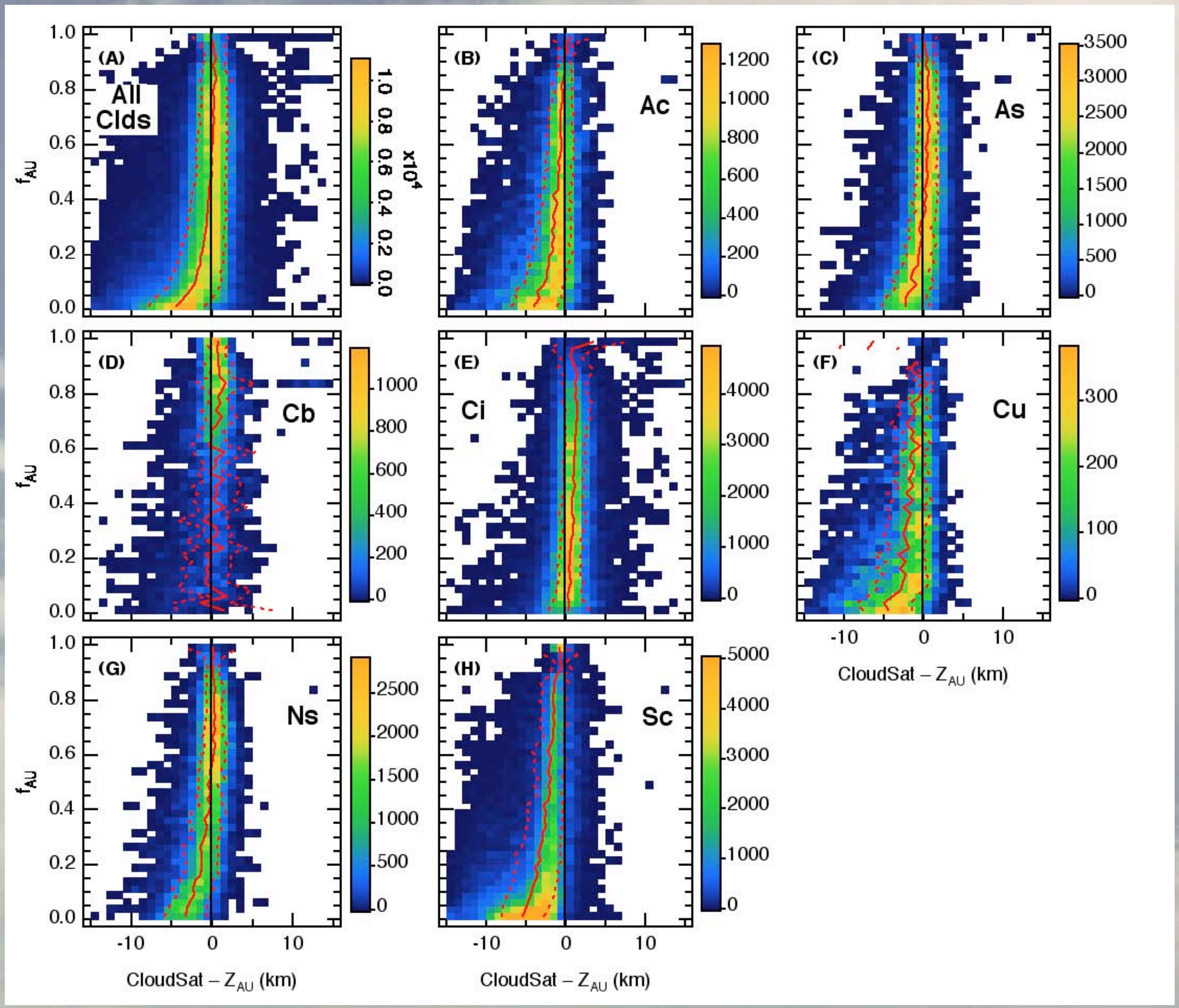
Frequency PDFs of CloudSat – AIRS CTH



Upper AIRS CTH –
Top Bin CloudSat CTH

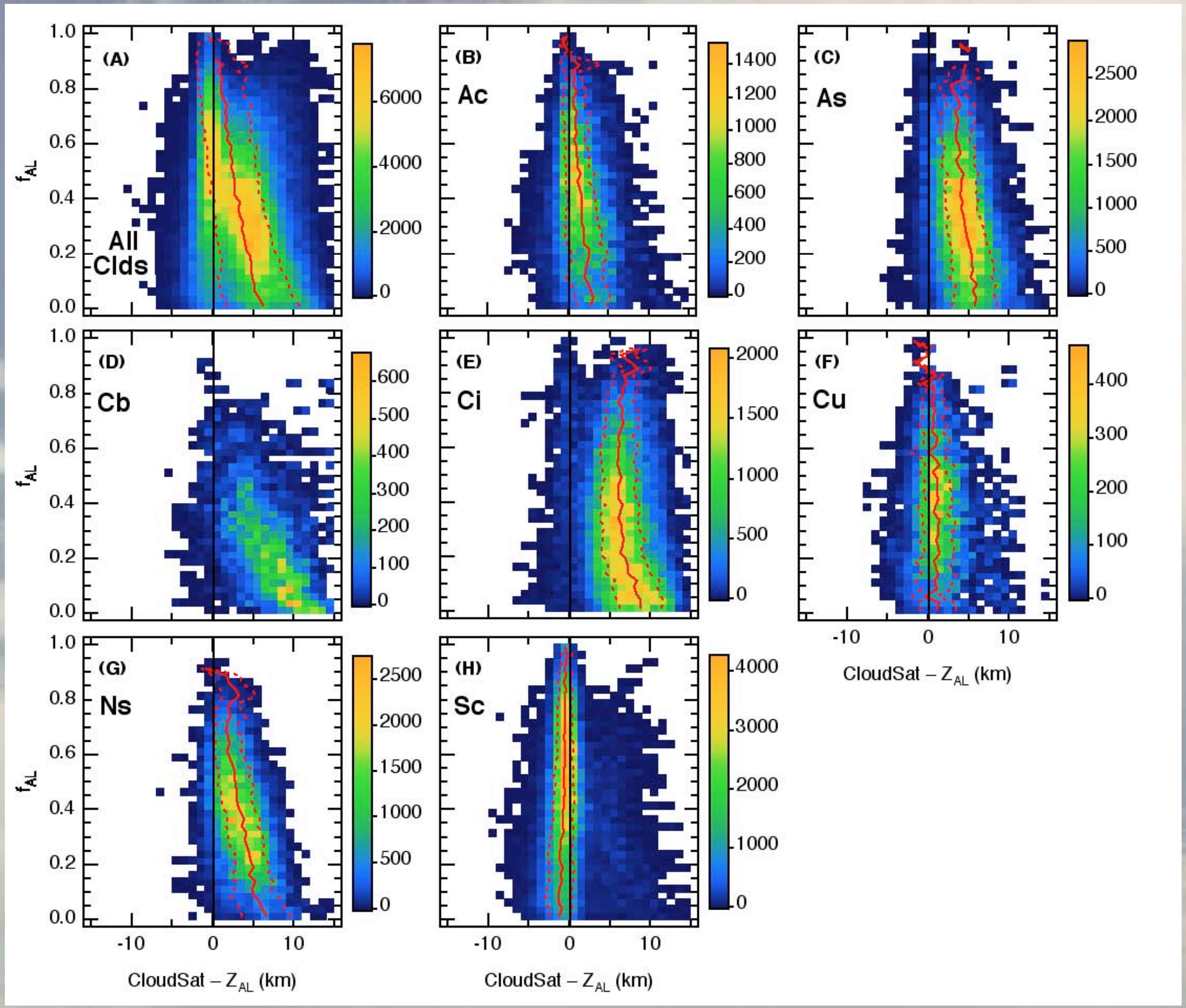
Lower AIRS CTH –
Top Bin CloudSat CTH

Cloud-type PDFs for Upper AIRS CTH



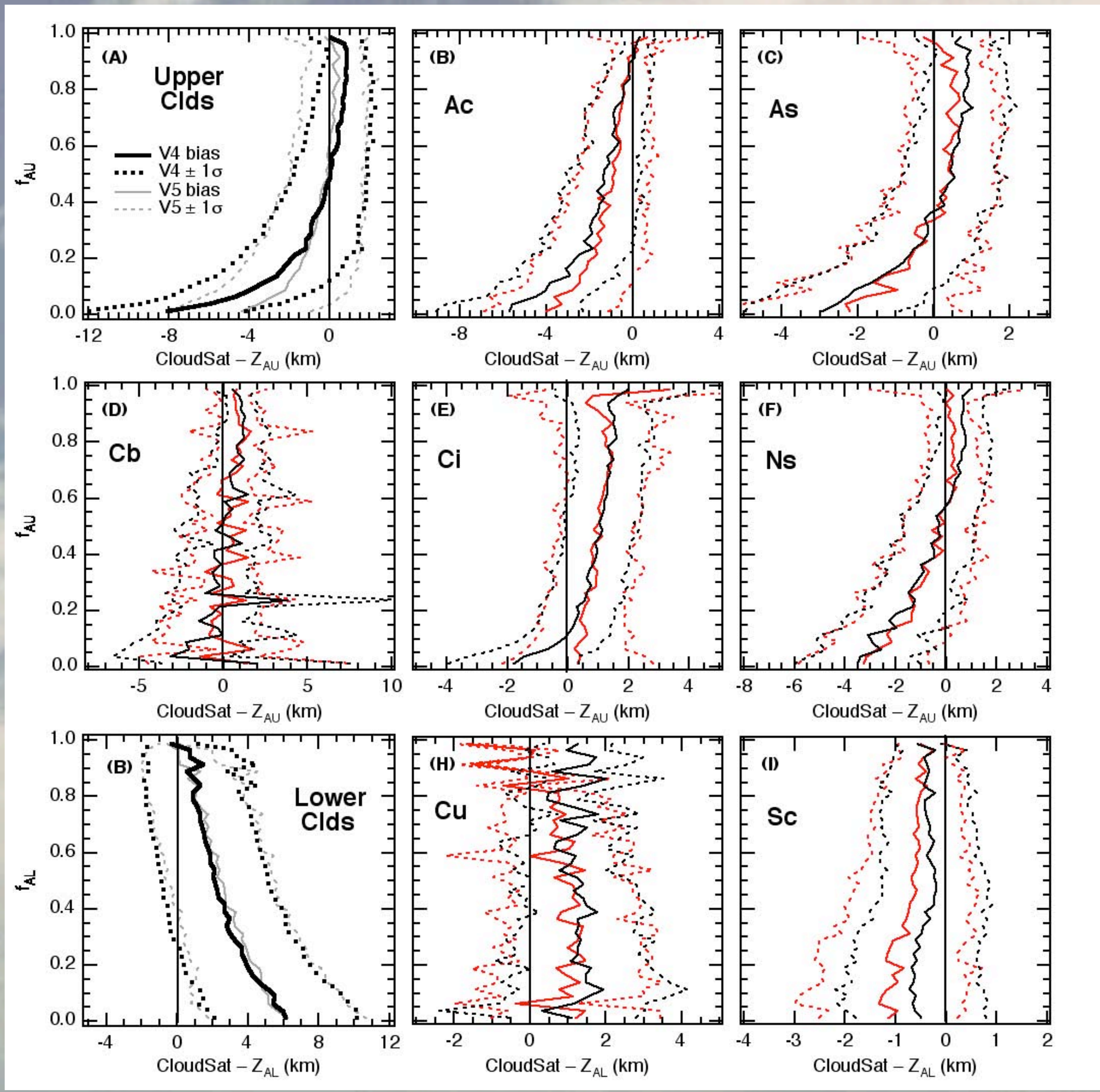
Partition
Upper AIRS CTH –
Top Bin CloudSat CTH
by Cloud Type

Cloud-type PDFs for Lower AIRS CTH



Partition
Lower AIRS CTH –
Top Bin CloudSat CTH
by Cloud Type

V4 vs. V5 Partitioned by Cloud-type



V4 and V5 Differences

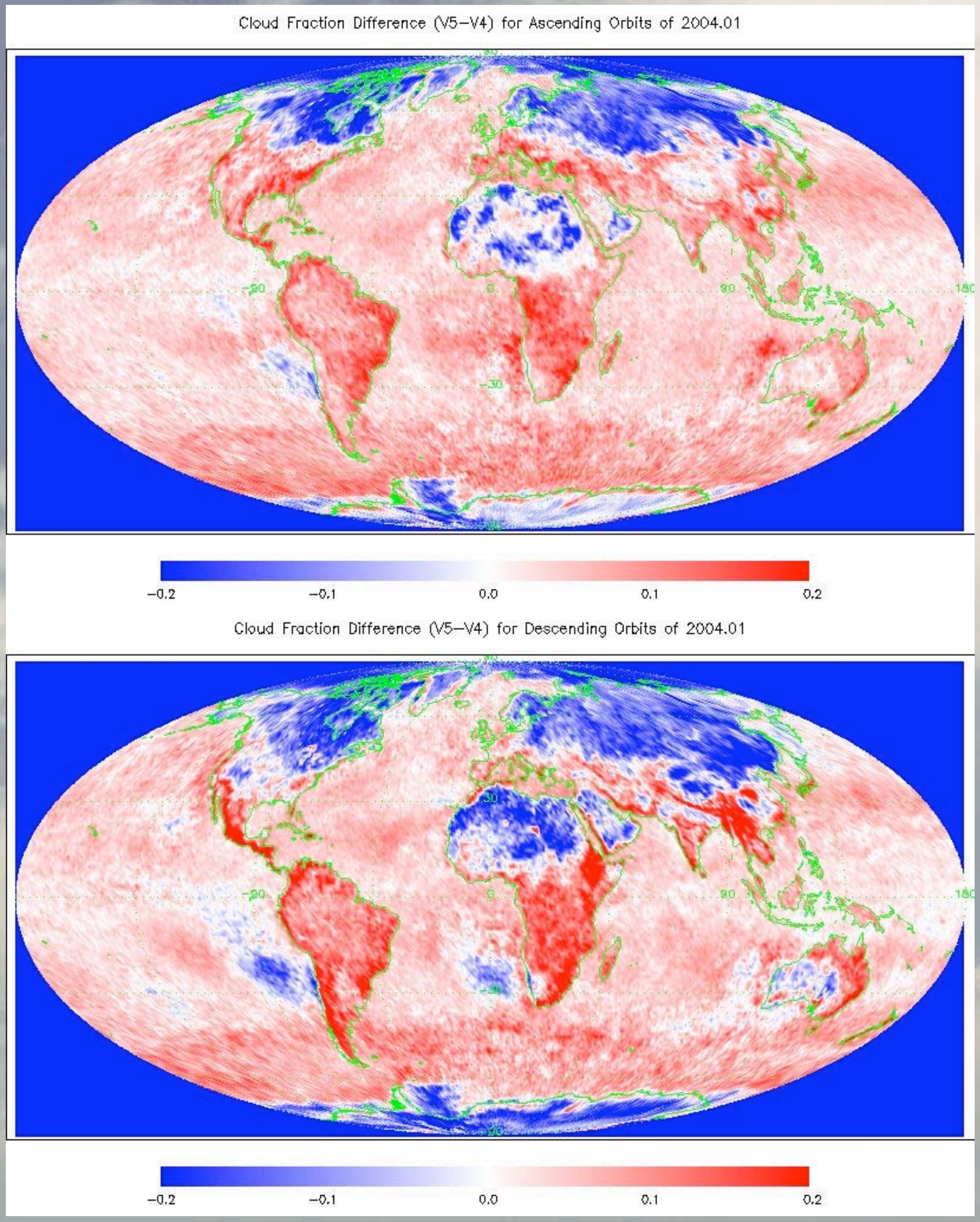
Certain cloud types much more spatially homogeneous

Cloud Type	% All FOVs Found	% All FOVs Homogeneous
Clear	66.8	17.5
Ac	16.0	7.1
As	19.7	14.1
Cb	3.1	2.6
Ci	21.6	12.6
Cu	6.2	1.2
Ns	9.8	9.2
Sc	46.9	7.3

Heterogeneous distributions of Clear, Ac, Cu, and Sc within AIRS FOVs

Homogeneous distributions of As, Cb, Ci, and Ns within AIRS FOVs

V4 vs. V5: Significant Sample Size Changes



V5–V4 Ascending 2004–01

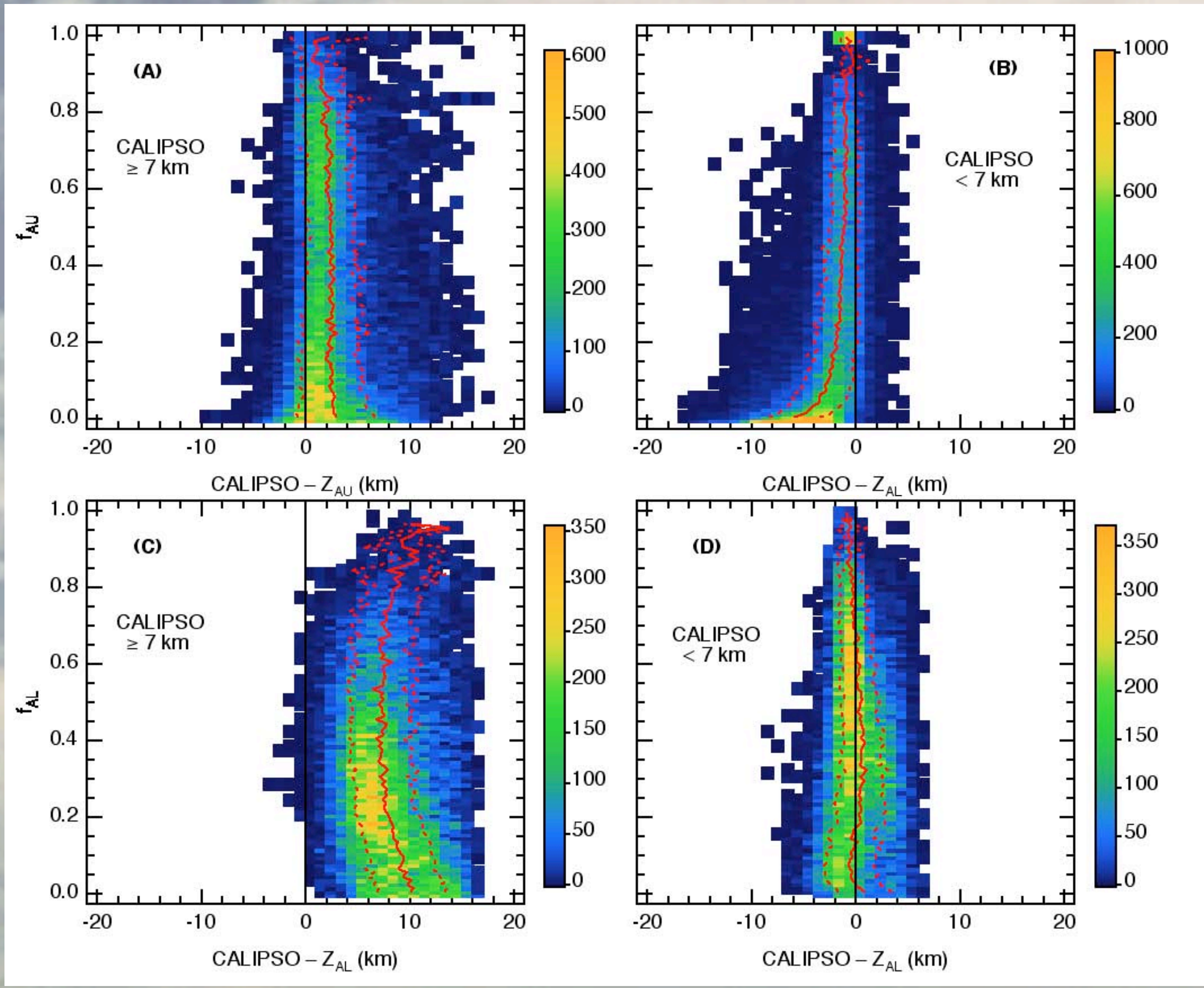
V5–V4 Descending 2004–01

Plots courtesy of Sung-Yung Lee

Frequency PDFs of CALIPSO – AIRS CTH

CALIPSO ≥ 7 km

CALIPSO < 7 km

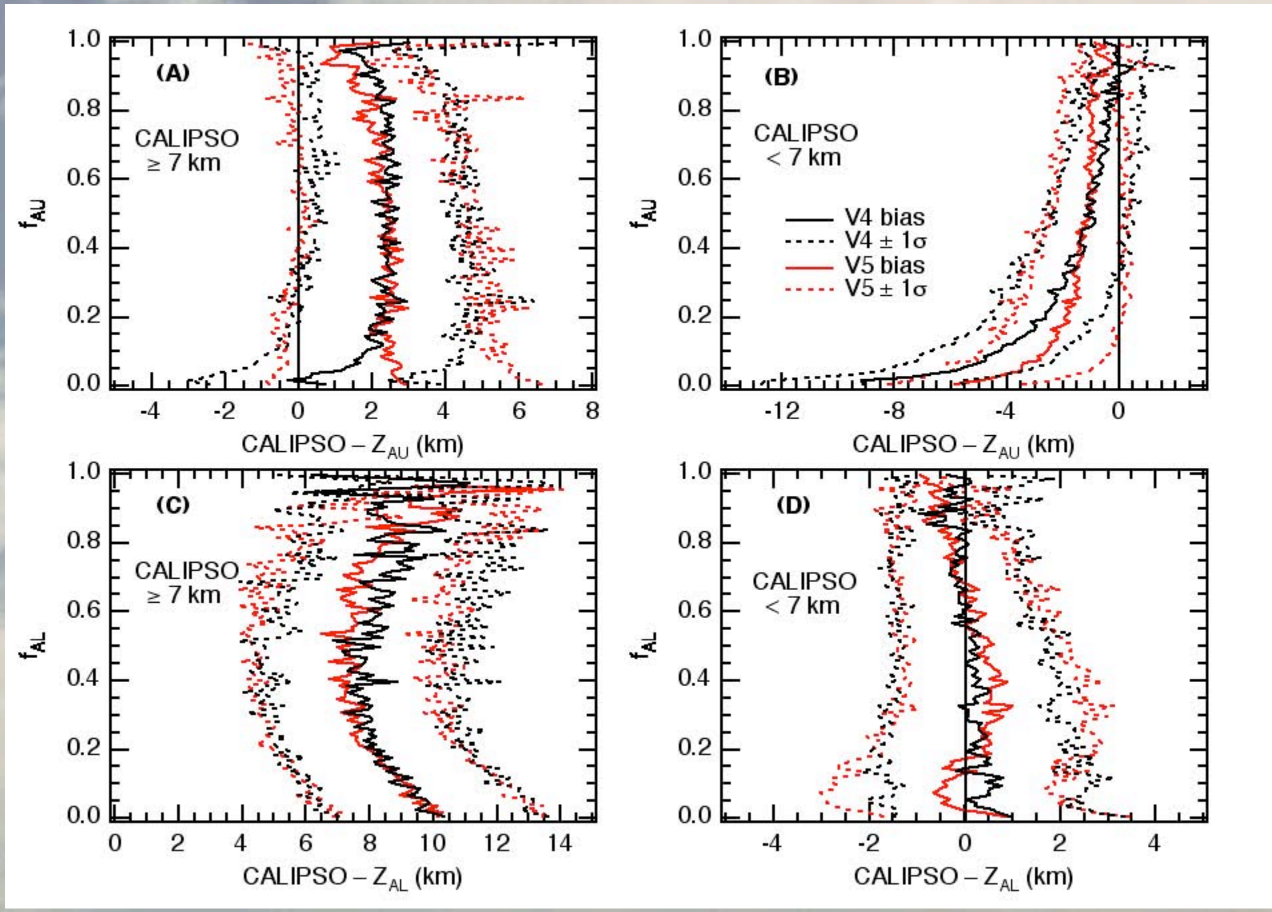


AIRS Upper CTH

AIRS Lower CTH

CALIPSO/AIRS V4 vs. V5 Differences

CALIPSO ≥ 7 km **CALIPSO < 7 km**



AIRS Upper CTH

AIRS Lower CTH

“Take Home” Messages

• CloudSat/CALIPSO and AIRS agreement dependent on cloud-type

Cloud Type	AIRS Layer	Bias	± 1σ Variability
All	Upper	–4.0 to 0.2	1.2–3.6
All	Lower	0.1 to 6.2	1.8–4.5
Ac	Upper	–4.0 to 0.2	0.7–3.0
As	Upper	–2.3 to 0.7	0.9–2.6
Cb	Upper	–1.4 to 1.6	0.9–4.0
Ci	Upper	0.2 to 1.5	1.1–2.8
Cu	Lower	–0.3 to 1.5	0.3–2.2
Ns	Upper	–3.3 to 0.4	0.7–2.5
Sc	Lower	–1.3 to –0.3	0.4–1.7

CALIPSO Z_{CLD}	AIRS Layer	Bias	± 1σ Variability
> 7 km	Upper	0.6 to 3.0	1.2–3.6
> 7 km	Lower	6.5 to 10.8	1.2–4.0
≤ 7 km	Upper	–5.8 to –0.2	0.5–2.7
≤ 7 km	Lower	–0.7 to 1.0	0.5–2.8

• AIRS missed/false detection rate lower with CALIPSO (good result)

• Certain cloud-types more heterogeneous within AIRS FOV (Clear, Ac, Cu, Sc)

• Differences between V4/V5 from certain cloud-types (Ac, As, Ci, Sc)